Muon Campus Cryogenics

Functional Requirements Specification

October 2, 2012

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2. REVISION HISTORY

Revision	Date	Section No.	Revision Description
1.0	October 2, 2012	All	Initial Release

3. INTRODUCTION

Fermilab is upgrading accelerator complex that will create more intense particle beams for experiments that explore neutrino interaction. The upgraded complex will enable planned muon experiments, Muon g-2 and Mu2e, that will explore rare sub-atomic processes and make precision measurements

The experiments utilize superconducting magnets that require cryogenic services. A cryogenic system to provide these services consists of four Tevatron Satellite refrigerators, compressor system, a cryogenic distribution system, and an axillary system necessary for the cryogenic system operation.

This document provides the functional requirements to be used for the design, fabrication, installation, commissioning and acceptance testing of a cryogenic system in support of the muon experiments.

4. DEFINITIONS

ACNET – Accelerator controls network

AP10 – Antiproton service building

CHL – Fermilab Central Helium Liquefier

DS – Mu2e detector solenoid

FESHM – Fermilab Environmental Safety and Health Manual

A0 –Compressor building at main ring location A0

MAWP – Maximum Allowable Working Pressure, a term that is used to define the safe pressure rating of a component or system

ODH – Oxygen Deficiency Hazard

PS – Mu2e production solenoid

TS - Mu2e transport solenoid

5. SCOPE OF WORK

Inclusions

Design, construction, installation, testing, and commissioning of the Muon Campus cryogenic system (*the Cryogenic System*) in support of experiments in the following configurations:

1. **Muon g-2 alone**

   Four superconducting solenoids [1]

2. **Mu2e alone**

   Three superconducting solenoids (PS, TS and DS) [2]

3. **Mu2e and Muon g-2 combined**

The Cryogenic System includes the following key components and sub systems:

1. Four model 2016C Mycom oil-flooded screw compressors located at the A0 compressor building;
2. Four Tevatron Satellite refrigerator cold boxes;
3. Four reciprocating dry expanders;
4. Four reciprocating wet expanders;
5. Four modified Tevatron valve boxes;
6. Refrigerator building interconnect cryogenic transferlines;
7. Single modified AP10 bayonet can;
8. Hard piped connection to interface Muon g-2;
9. Mu2e to the refrigerator building transfer line with a bayonet can at the refrigerator end and a distribution box at the Mu2e end;
10. A0 compressor building to the Muon Campus helium piping system(suction and discharge headers);
11. Refrigerator building interconnect piping system;
12. Modified CHL's vertical liquid nitrogen dewar;

13. Two 30,000 gal helium gas storage tanks;
14. Gas management system;
15. Instrument air system;
16. ODH systems;
17. Local refrigerator and compressor controls.

Exclusions

Non-cryogenic related equipment is excluded from this FRS, e.g. civil structures, A0 compressors cooling water system, electrical power sources, accelerator controls, shielding, support structures, etc.

6. KEY ASSUMPTIONS, INTERFACES AND CONSTRAINTS

(a) Necessary building, civil structures, any concrete supports and piers, and utilities are available prior to the installation of the Cryogenic System;

(b) ACNET is utilized for the Cryogenic System control;

(c) Data exchange between experiments and the cryogenic system will be via ACNET control system utilizing software devices;

(d) Experiments will provide their own protection from pressurization beyond components MAWP. The cryogenic system provides protection from over pressure to devices that fall within the scope of the Cryogenic System only;

(e) Four Tevatron satellite refrigerators are utilized to provide cryogens to the experiments;

(f) Single Tevatron satellite refrigerator is capable of operating at its nominally rated capacity listed in Table 1;

(g) Muon g-2 and Mu2e solenoids heat loads are within the estimated maximum range listed in this document;

(h) Each experiment will have features to minimize its quench effect on the Cryogenic System;

(i) The Cryogenic System support of cooldown for either experiment is limited to its nominal capabilities of providing liquid cryogens, helium and nitrogen. The

Cryogenic System has no special features to control cooldown speed or temperatures outside of its standard Tevatron design parameters;

(j) Accelerator Division Cryogenics support of the Cryogenic System safety review is limited to its scope;

(k) Maximum cryogenic load:

Muon g-2

Liquefaction load – 1.4 [g/sec]

Refrigeration load – 300 [W]

LN2 Shield flow rate – 1.6 [g/sec]

Mu2e

Liquefaction load – 0.8 [g/sec]

Refrigeration load – 350 [W]

LN2 Shield flow rate – 20 [g/sec]

(l) Operating Parameters (nominal and tolerances):

Muon g-2

Operating pressures

Single phase pressure – $P \geq 13 \pm 1$ [psig]

Two phase pressure – $5 \leq P \leq 7$ [psig]

LN2 supply pressure – $P \geq 20$ [psig]

Operating temperatures - at saturation [K]

Mu2e

Operating pressures

Single phase pressure – $P \geq 13 \pm 1$ [psig]

Two phase pressure – $5 \leq P \leq 7$ [psig]

LN2 supply pressure – $P \geq 20$ [psig]

Operating temperatures - at saturation [K]

Table 1 Tevatron Satellite Refrigerator Maximum Theoretical Capacity [3]

Mode	Units	Capacity
Liquefaction	[g/sec]	4.2
Refrigeration	[W]	625

7. REQUIREMENTS

(a) The Cryogenic System is expected to operate for 20 years with an estimated shutdown period of one month every year;

(b) The Cryogenic System and its components are subject to comply with FESHM, in particular, FESHM chapters 5031, 5031.1, 5031.3, 5032, 5033, 5064;

(c) The refrigerator building area ODH classification shall not exceed ODH class 1 as defined in the FESHM 5064;

(d) All of the components and subsystems will be manufactured using Fermilab QA procedures and standards;

(e) Insulating vacuum and thermal shield system shall provide for reasonable static heat load;

(f) The Cryogenic System shall provide for proper protection of process fluids from contamination;

(g) All components shall be designed for flexibility to allow thermal contraction while maintaining proper restraint for all over-pressure conditions;

(h) The Cryogenic System shall support simultaneous steady state operation of both experiments, Muon g-2 and Mu2e. It shall provide for independent operation of the two experiments, including transient modes, e.g. warm-up, cooldown, etc.;

(i) The Cryogenic System shall be able to cope with heat load fluctuations;

(j) It should be possible to connect and/or isolate Mu2e magnets from the transfer line while under cold conditions;

(k) The Cryogenic System shall be design to reduce perturbations during fault conditions;

(l) It should be possible to commission the Cryogenic System independently of experiments;

(m) The Cryogenic System design shall allow to minimize loss of cryogens;

(n) The Cryogenic System shall provide nitrogen gas service to g-2 experiment;

(o) The design of the Cryogenic System shall provide redundancy of its components.

8. REFERENCES

1. Design Report BNL AGS E821, Muon g-2 DocDB, Document 125-v1
2. Mu2e Design Report, TBD
3. A Report on the Design of the Fermi National Accelerator Laboratory Superconducting Accelerator, May 1979, p.71